

LLRF 2019



SOFTWARE FOR APSU LLRF



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In collaboration with
Oak Ridge National Laboratory



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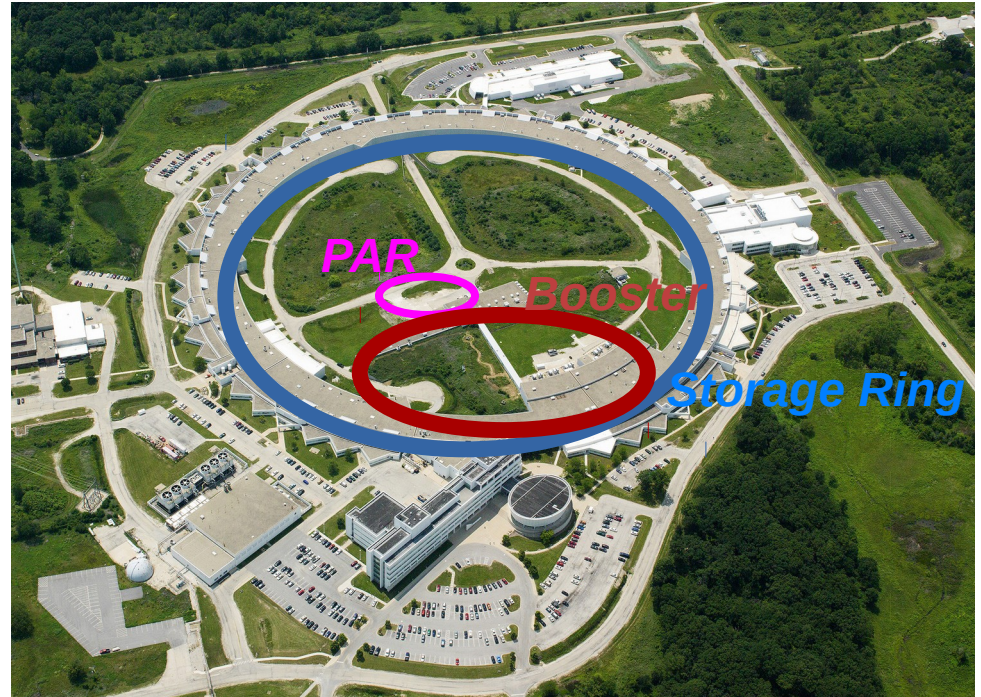
OUTLINE

- **Introduction and Background**
- APS Data Acquisition Software Infrastructure
- The LLRF EPICS 7 IOC
- User Interface
- Thanks

UPGRADE OF LLRF

Upgrading APS from Analog to Digital LLRF

- Storage Ring
- Booster
- Particle Accumulator Ring



COMMON MICRO-TCA PLATFORM

- FPGA Advanced Mezzanine Carrier (AMC) with RF FPGA Mezzanine Cards (FMC)
 - FPGA firmware developed at Oak Ridge National Laboratory
- PCIe 4x Backplane
- Linux Blade running EPICS 7 IOC
- Common Hardware for APS Machines (PAR, SR, Booster)
- Common Software Platform



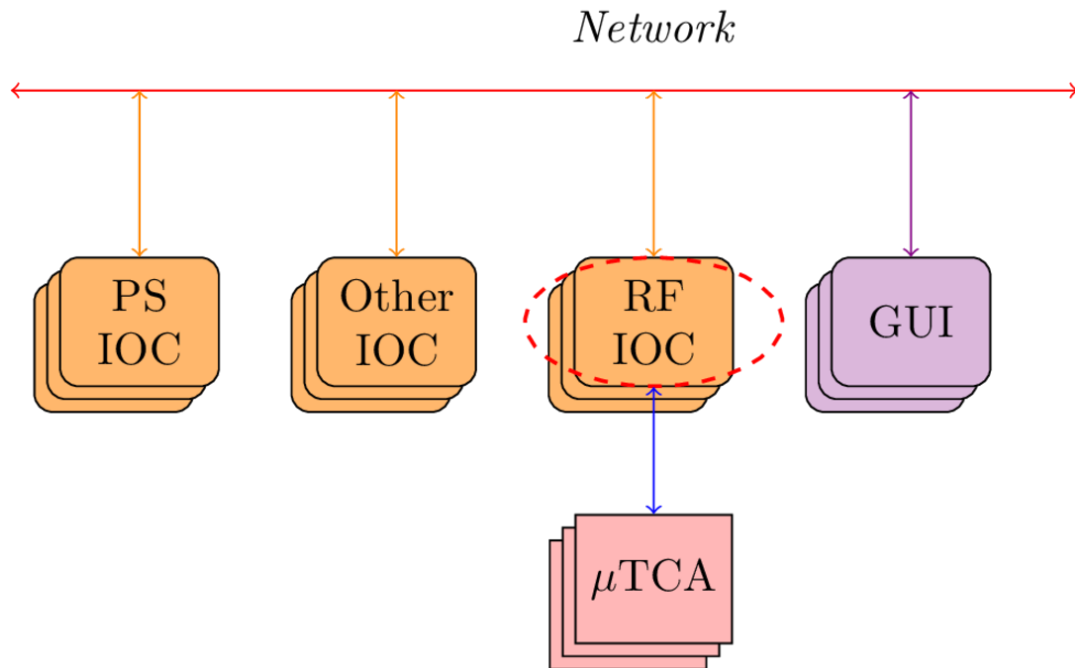
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SOFTWARE INFRASTRUCTURE

Experimental Physics and Industrial Control System (EPICS)

- Distributed digital control system
- Version 3 controls APS
- Input-Output Controller (IOC)
 - Computer that connects to hardware and publishes “Process Variables” (PVs) on network.
- Clients access PVs
 - GUI or Scripts to control Accelerator Systems.

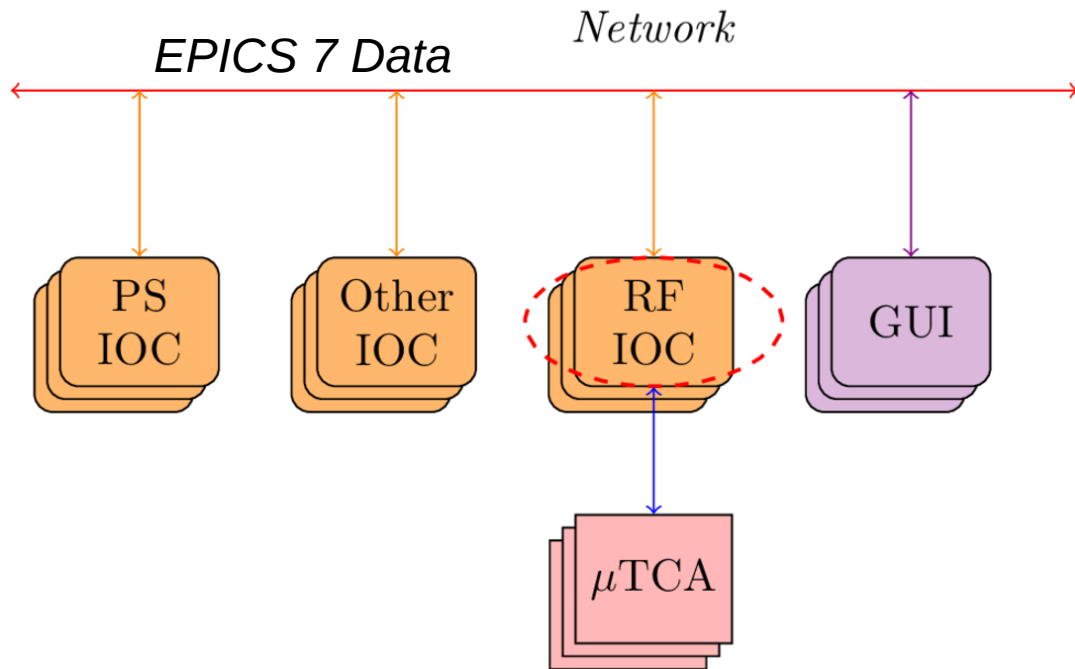


SOFTWARE INFRASTRUCTURE

Experimental Physics and Industrial Control System EPICS

- Version 4 adds
 - Structured Data
 - Reliable Data Streaming
- EPICS 3 + 4 = 7

```
LLRF_Data {  
    float Sample Rate;  
    float [ ] I_Data;  
    float [ ] Q_Data;  
    float [ ] Mag;  
    float [ ] Phase;}
```



SOFTWARE INFRASTRUCTURE

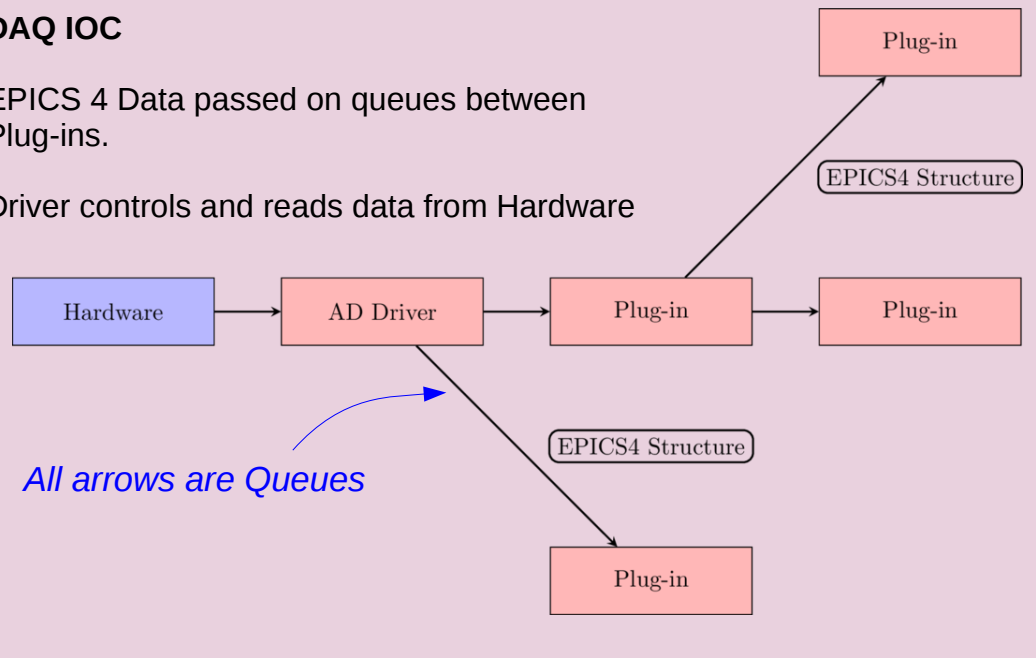
EPICS Area Detector for EPICS 7 Accelerator Data

- Area Detector
 - EPICS tools for acquiring images from large x-ray detectors.
 - IOC with Driver and set of Plug-ins.
 - Image passed between Driver and Plug-ins on queues
- AD + EPICS 4
 - Pass EPICS 4 accelerator data rather than images
- AD+EPICS 7 is basis of APS software infrastructure

DAQ IOC

EPICS 4 Data passed on queues between Plug-ins.

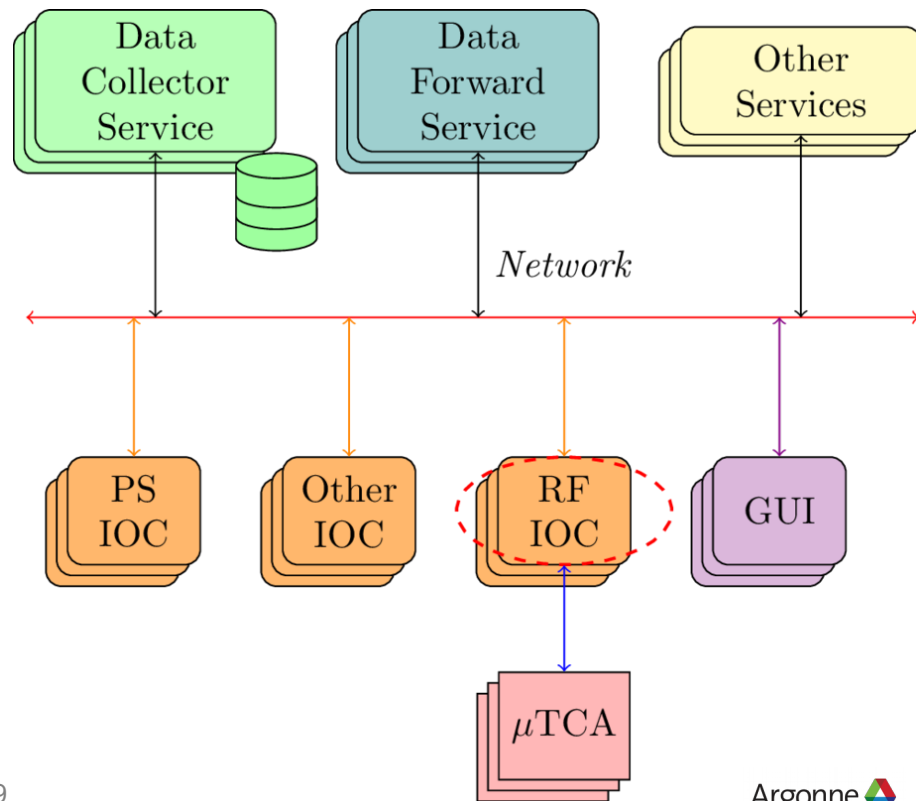
Driver controls and reads data from Hardware



SOFTWARE INFRASTRUCTURE

Data Acquisition System (DAQ)

- Many EPICS 7 IOCs
 - Data Forwarding
 - Data Storage
 - Data Processing
 - Others
- Time Stamping System
- Real-Time Visualization
- User Command Line Tools
- Many Data Protocols



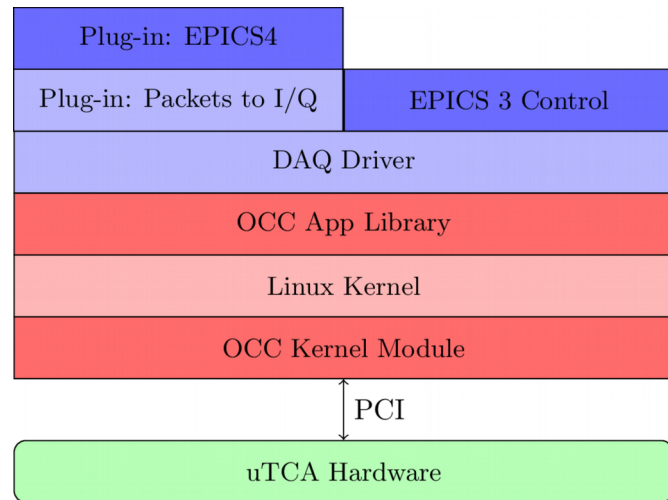
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LLRF IOC

Software Stack

- Micro-TCA crate send/receive PCIe
- OCC Kernel module (red) handle PCIe Data
 - Linux use OCC module for DMA.
 - OCC library allow IOC access to PCIe data.
 - Developed at Oak Ridge National Laboratory
- IOC (blue)
 - Control Micro-TCA via EPICS3
 - Get PCIe data, convert to EPICS4 I/Q data.
 - Stream EPICS4 over network.



LLRF IOC

Automatic Screen and Code Generation

- Synchronize Software Development at ANL with Firmware Development at ORNL.

- Work flow:

- Update Firmware and Compile
- Document in Spreadsheet
- Run Python
- Compile Software
- Run new IOC Driver SW.

Update FPGA FW

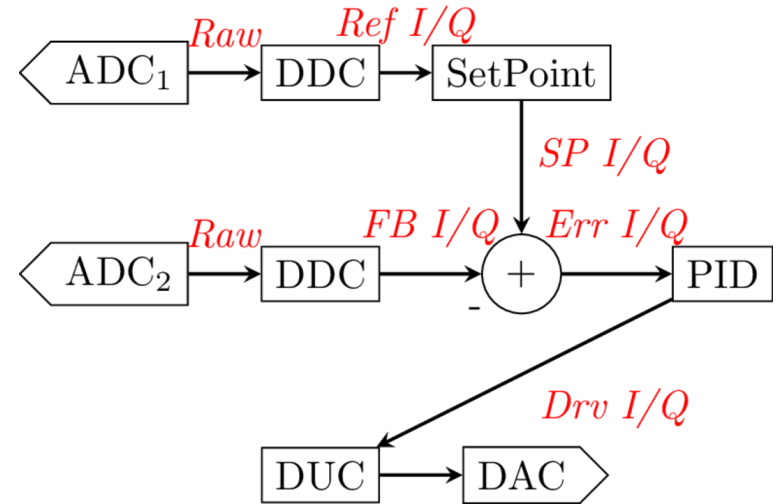
Update Spreadsheet

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127	0x0000006A	0x0000006A	0x0000006A								

LLRF IOC

Real Time Data Flow

- FPGA runs PID RF Control loop
 - Controls RF mag/phase in cavities
- Wave forms taken from several points in PID loop.
- For loop setup, diagnostics, monitoring.
- Real-time streaming of I/Q, Mag/Phase data.

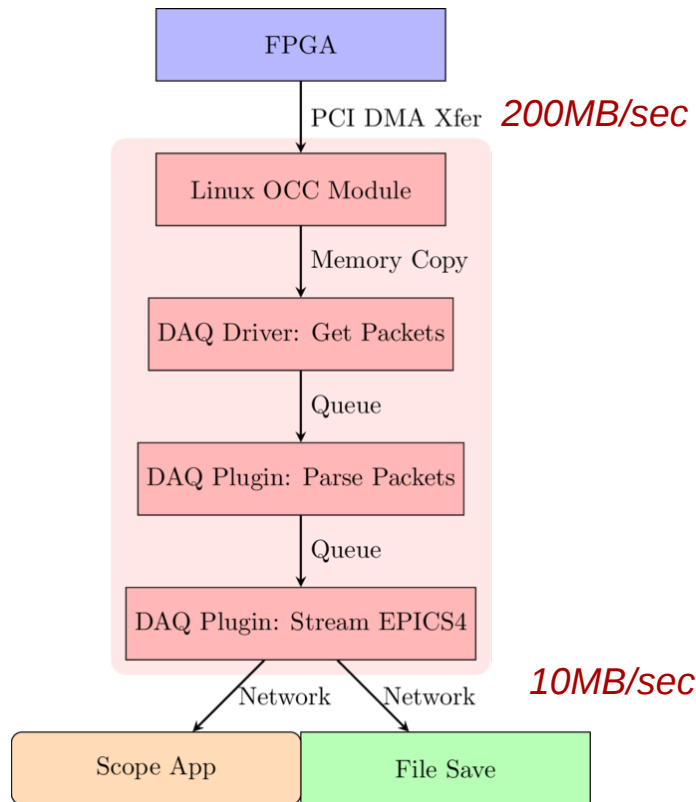


*In Red are signals
streamed from PID loop.*

LLRF IOC

Real Time Processing

- Driver runs on designated core
 - Gets PCIe packets from OCC and places in queue
- Processing Plug-in
 - Parse PCIe packets
 - Create I/Q wave forms in EPICS 4 Structures
 - Calculate Phase/Magnitude vectors in EPICS 4
- Streaming Plug-in
 - Stream I/Q, Phase/Mag as EPICS4
 - For file store, real-time display

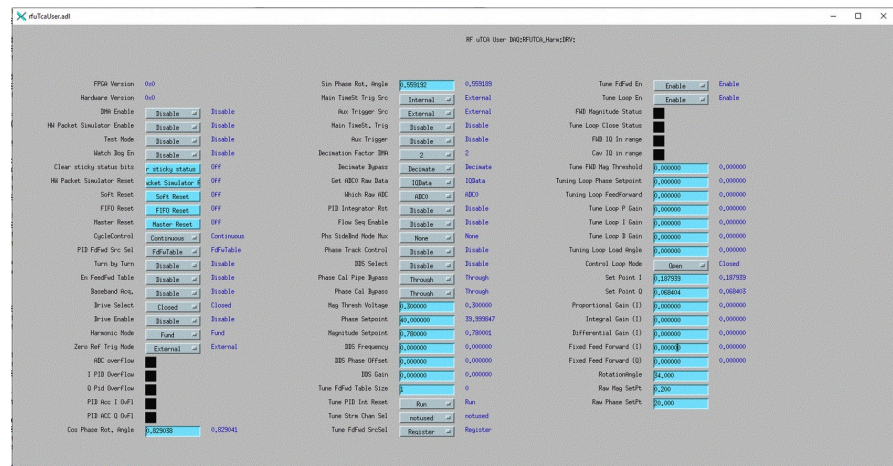
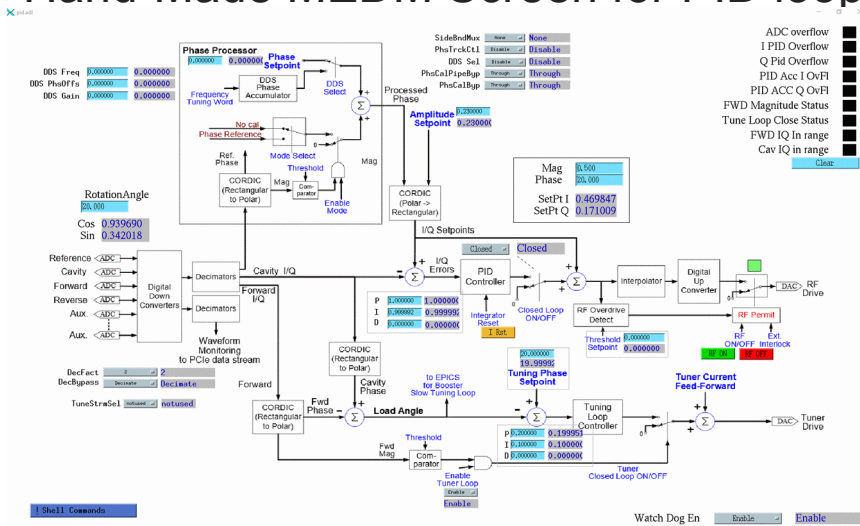


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Control GUI

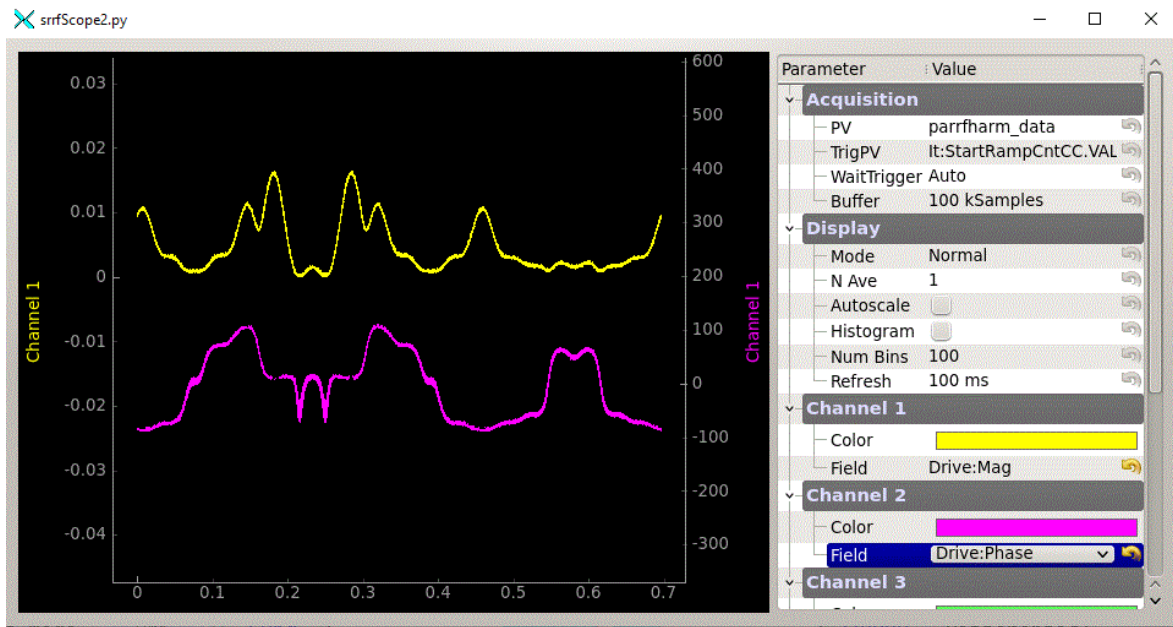
- Hand-Made MEDM Screen for PID loop.



USER INTERFACE

Scope Application

- Real-Time Display of I/Q, Phase/Mag wave forms.
- Time or Frequency Domain
- Trace averaging
- Up to Four waves at once.
- Triggered on EPICS PV
 - 2Hz Booster cycle trigger scope.



THANK YOU FOR LISTENING

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E. BREEDING, K. VODOPIVEC
OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TN, USA